<u>Amendments to the Specification:</u>

Please replace paragraph [002] with the following amended paragraph:

[002] Non-Destructive Testing (NDT) is used to ensure product integrity, product reliability, prevent failure[[,]] and ensure [[operational]] <u>operation</u>. Generally, NDT can be divided into two categories, volumetric (those involved with the internal integrity of a structure or part) and surface (those involved with assessment of only the surface of the structure).

Please replace paragraph [003] with the following amended paragraph:

[003] One type of NDT is Infrared (IR) transient thermography [[(IRTT]] <u>(IRTT)</u> that relies upon temporal measurements of heat transference through an object to provide information concerning the structure and integrity of the object. Conventionally, as described in United States Patent No. 5,711,603 to Ringermacher et al., entitled "Nondestructive Testing: Transient Depth Thermography" the technique involves heating the surface of an object of interest and recording the temperature changes over time of very small regions or "resolution elements" on the surface of the object.

Please replace paragraph [008] with the following amended paragraph:

[008] A further aspect of the present invention is [[transient thermography]] a method for non-destructive testing of a structure wherein energy is deposited within at least a portion of a volume of a structure and transient temperatures are detected at a surface of the structure caused by diffusion of the deposited energy.

Please replace paragraph [011] with the following amended paragraph:

[011] To achieve these and other advantages and in accordance with the purpose of the present invention, as embodied and broadly described, the present invention can be characterized according to one aspect of the present invention [[comprises]] <u>as</u>

comprising a method for non-destructive testing of a structure wherein energy is deposited within at least a portion of a volume of a structure and transient temperatures are detected at a surface of the structure caused by diffusion of the deposited energy.

Please replace paragraph [017] with the following amended paragraph:

[017] Fig. 4 [[depicts]] is a Prior Art illustration depicting a typical Boron/Epoxy skin aluminum honeycomb composite;

Please replace paragraph [018] with the following amended paragraph:

[018] Figs. 5A – 5D [[illustrate]] are Prior Art illustrations depicting flaw types of the honeycomb composite of Fig. 4;

Please replace paragraph [025] with the following amended paragraph:

[025] The results of the technique are dramatic. An induction coil moved across the surface of the composite that is being imaged by a sensitive infrared focal plane appears to "light up". As depicted in Fig. 1, inductive heating of a honeycomb structure 100 for example in a honeycomb assembly 110, a honeycomb shaped pattern forms in [[about]] approximately one half second where there is a good thermal path from the honeycomb 110 through skin 120 to the surface. In areas where there is a flaw, for example a disbond or delamination 130 in the skin 110, the amount of thermal energy transported to the surface is lowered giving little or no image. As the heat diffuses laterally, the image appears to blur with the honeycomb pattern gradually washing out to a uniform heat signature. The effect is a transfer of the energy to the skin 120.

Please replace paragraph [026] with the following amended paragraph:

[026] The color-coding [[is]] of honeycomb 110 represents temperature with red representing the highest and blue representing the least rise above ambient. First the energy is deposited in the ends of the honeycomb in a length that is proportional to the skin depth, in this embodiment approximately the skin depth. For a fixed coil 140 translation speed, a constant amount of energy is left in each honeycomb. As this thermal energy diffuses down the length of the honeycomb 110 and into the skin 120, the average temperature decreases. The energy in the skin 120 diffuses in two directions with a correspondingly more rapid fall-off in temperature. Eventually, the diffusion front reaches the surface where it is detectable by a sensitive IR camera. Note that where there is a disbond flaw 130 energy cannot flow and the only route for the honeycomb tip to lose its energy is down the length. A person of ordinary skill in the art will appreciate that the illustration depicted in Fig. 1 is highly schematic and in reality, there would be a continuous distribution of temperature – not uniform temperatures in each small region.

Please replace paragraph [027] with the following amended paragraph:

[027] Because infrared cameras are very sensitive and can easily detect temperature changes of less than [[one fiftieth]] <u>one-fiftieth</u> of a degree, it takes very little energy injected into the material to make the disbonds visible. Because the energy is injected directly under the region to be inspected, the technique is very specific.

Please replace paragraph [028] with the following amended paragraph:

[028] Fig. 2 depicts several frames from a video clip 210, 220, [[230]] <u>230,</u> 240 and 250 of a machined flaw that simulates a disbond. In this figure, time progresses from left to right. The disbond flaw 130 and several of the effects discussed above are apparent.

Please replace paragraph [030] with the following amended paragraph:

[030] The speed of the technique is remarkable. In tests conducted a technician with an induction coil wand of approximately 100 mm in diameter can stimulate a honeycomb panel 300 mm [[by500]] by 500 mm in under 10 seconds. The speed is limited mostly by the scan speed of the IR camera over the surface. A high-resolution camera that can view the entire surface can record the results directly. Using this technique it is estimated that a single side of one F-15 vertical stabilizer could be scanned in approximately 15 minutes. Of course, in practice, repositioning the equipment would increase the inspection time but it is easy to imagine a system that could inspect both sides of the stabilizer in less than two hours using a single inspector in a "cherry picker" platform, as shown in Fig. 8.

Please replace paragraph [031] with the following amended paragraph:

[031] [[This]] The speed of scanning an object or structure gives the technique of the present invention a tremendous advantage over ultrasonic or laser interferometric techniques that require the precise and time consuming scanning of a beam of sound waves or coherent light across the surface. This technique has the potential for inspecting a wide variety of structures due to the range of parameters available to work with. By understanding the relative time constants and RF frequency response of the material, combination of parameters to enable the technique to work for many different material combinations can be selected.

Please replace paragraph [034] with the following amended paragraph:

[034] Induction is a fundamental electromagnetic (EM) process [[in]] by which a changing magnetic field induces a current in a conductor. Induction is one of the

foundations of EM theory and the basis for the operation of electric motors, transformers and many other devices. When conducting materials are formed into coils and time varying current is passed through them, a magnetic field is generated. When this coil is brought close to a conducting medium, a current is induced in the material that attempts to create a magnetic field that just cancels the field created by the coil. The driving coil senses this opposing effect through an effect called mutual inductance, which is the basis for "eddy current" NDI technology, labeled after the type of currents induced in the material. In eddy current NDT, changes in the detected mutual inductance are interpreted to indicate the presence of flaws in the material that disrupt the induced current.

Please replace paragraph [035] with the following amended paragraph:

[035] In a perfect conductor the induced currents are completely effective in opposing the induced magnetic field and it does not penetrate into the material. The familiar demonstration of a magnet suspended above a superconductor [[show]] <u>shown</u> this effect. In normal conductors, however, there is a resistance to current flow in the material and the field penetrates into the material. There are two effects from this: First the opposing eddy currents reduce the magnetic field as one moves into the material so that the field and eddy currents decrease exponentially with depth into the material. The current density then varies with distance into the material as <u>predicted by Equation 1</u>:

Please replace paragraph [040] with the following amended paragraph:

[040] The second effect from the finite resistance of the material is that there is heat dissipated through ohmic losses. The volumetric rate of heat generation is given [[by]] <u>as follows:</u>

Please replace paragraph [042] with the following amended paragraph:

[042] Where J is the current density in amps/ m^2. This heat dissipation is the term on the right hand side of the heat conduction equation and is the basis for our innovation. It can see from the equation for skin depth that by changing the frequency for a given material, the user can change the depth to which heating is induced. This provides a powerful tool for probing a material using transient thermography.

Please replace paragraph [046] with the following amended paragraph:

[046] Transient thermography is a relatively recent NDI technique made possible by the development of sensitive infrared focal plane arrays. These devices are effectively video cameras that "see" in the infrared region of the spectrum where the radiation emanating from a body is composed of emitted radiation as well as reflected radiation. Because the devices are very sensitive, temperature differences as small as 0.020 K can be detected. Infrared cameras are used in NDI in [*steady state conditions*] <u>steady state conditions</u> to observe hotspots in electrical equipment, leaky insulation in [[homes,]] <u>homes</u> and industrial plants. Interest here is in the use of these sensitive detectors in observing transient events.

Please replace paragraph [051] with the following amended paragraph:

[051] Heat conduction <u>in</u> a solid is described by Fourier's law of heat conduction, which states that the rate of energy conducted through a solid is proportional to the gradient of temperature in that solid. When incorporated into the equation for conservation of energy in a solid the following equation is easily derivable for isotropic solids:

Please replace paragraph [053] with the following amended paragraph:

[053] where k is the thermal conductivity in W/m K, ρ is the density in kg/m^3, T is temperature in K, c is the specific heat in J/kg K and Q is the rate of volumetric heat

addition in W/ m^3. This is a classical time dependent diffusion equation, which is more apparent by dividing through by ρc [[to get]] <u>resulting in</u>:

Please replace paragraph [060] with the following amended paragraph:

[060] This relationship is central to understanding the process of transient thermography in that one point of interest in the present invention is the relative time for diffusion processes required to produce measurable temperature changes on a surface. By way of example, if in Fig. 1, the aluminum honeycomb 110 has a wall thickness on the order of 0.1 mm and a width of 50 mm the time for temperature [[nonuniformity]] <u>non-unifromity</u> across the wall thickness to level out through diffusion is 0.1 msec, while the time constant for dissipation down the length of the honeycomb cell is 30 [[sec]] <u>seconds</u>. For the boron/epoxy skin 120, the thickness is approximately 2 mm and the cell size of the honeycomb is approximately 5 mm. This implies that the time for thermal energy to diffuse through the skin in the normal direction is approximately 0.08 sec while lateral [[nonuniformities]] <u>non-uniformities</u> in the skin with scale lengths the size of the honeycomb cell size dissipate is about 3.0 [[sec]] <u>seconds</u>.

Please replace paragraph [063] with the following amended paragraph:

[063] A typical composite structure 400 is shown in <u>Prior Art</u> Fig. 4. This construction is used on some major aerodynamic surfaces for the F-14 and F-15 fighter aircraft. The skin is made up of several layers of boron fiber layers 410 impregnated with epoxy. The skins depicted are bonded to aluminum honeycomb 420 with epoxy 430 and have a wall thickness of 100 microns.

Please replace paragraph [064] with the following amended paragraph:

[064] Note that the skin thickness may vary from 2 to 5 mm while the width of the honeycomb can vary from 0 to 100 mm. There are four major categories of flaws that are typically of interest, as shown in Prior Art Figs. 5A –5D. They are:

Please replace paragraph [068] with the following amended paragraph:

[068] [[Inter- laminar]] Inter-laminar water ingress.

Please replace paragraph [077] with the following amended paragraph:

[077] An alternate embodiment of the present invention is depicted in Figure 8. In this embodiment the operator scans [[the]] with an Induction coil in the form of a wand. The IR camera is mounted on his head along with a head mounted display. [[Under this option]] In this embodiment the operator would be placed near the stabilizer in a cherry picker or scaffold and would scan the surface of the stabilizer manually. A second visible camera could be mounted on his headgear to record the position accurately.

Please replace paragraph [078] with the following amended paragraph:

[078] In a further embodiment, as shown in Fig. 9 [[.]] an operator would wear the IR camera with a head mounted display and manually sweep the RF wand over the surface. This arrangement allows for a high level of interaction by the operator and enables the operator to examine questionable spots more carefully. The head mounted display allows viewing the scene normally in addition to through the camera. A second camera for imaging in the visible spectrum and bore sighted can be employed in an alternate embodiment of the present invention, wherein the resulting video stream is recorded perhaps with [[a]] and accompanying narration on a digital video recorder.

Please replace paragraph [081] with the following amended paragraph:

[081] The use of composites in aviation is widespread. In addition to boron/epoxy skins that were the focus of the proposed activity, the present invention is capable of being employed on a variety of other composite skins including carbon/epoxy, graphite/epoxy, Kevlar/epoxy, and glass/epoxy materials in a wide range of industries, such as, but not limited too, aviation, military applications, automotive industry, etc. While graphite and carbon materials do have conductivity greater than boron, their values are still orders of magnitudes lower than aluminum or titanium. Therefore, a frequency for stimulation can be selected which will penetrate the skin to the conducting under layer. In addition to composite skins, many aircraft have special coatings designed to camouflage or provide radar [[properties]] <u>properties.</u>

Please replace paragraph [082] with the following amended paragraph:

[082] In addition to detecting disbond and delaminations, the present invention is capable of locating conducting elements in a composite lay-up. Threaded inserts can be located from the opposite surface that may be more accessible, for example. Composite structures such as turbo fans or helicopter rotors are also prime candidates for inspection using [[our technique]] <u>the present invention</u>.

Please replace paragraph [083] with the following amended paragraph:

> [083] Although boron/epoxy structures are principally used only for repairs in the commercial aircraft arena, the use of other composites is wide spread. For instance, Boeing® uses Kevlar®/epoxy and carbon/epoxy structures in the airplane manufacturing for the 757, [[767,]] <u>767</u> and 777 which have extensive composite elements. Also the new versions of the 737 have been redesigned with composite panels.

Please replace paragraph [084] with the following amended paragraph:

[084] Many aerospace structures employ composite structures to save weight or control thermal loads. This technique will be very valuable for inspecting bonded structures consisting of insulation over metal. Two obvious applications are for the Space Shuttle in testing the bonding of the sprayed isocyanurate like foam insulation on the external H2/O2 tank and in testing the bonding of the ceramic tiles to the shuttle skin. Because both of these structures involve electrically insulating layers bonded to conducting sub structures, they are ideal candidates. In addition, many outer-space [[space]] structures consist of composite booms or joists attached to metal end fittings and are perfect candidates for the present invention.

Please replace paragraph [085] with the following amended paragraph:

[086] In the automotive industry composites are being widely adopted for body panels and frame components. A series of QC tools based on the present invention technique could be used to assure the integrity of the bonding and attachment points. [[Additional]] Additionally, applications [[application]] in monitoring [[coatings]] coating integrity also exist. In addition to coatings and composite body panels, there may be an application in QC tests for castings such as engine blocks and engine heads. Advanced building materials often rely on a composite structure consisting of an insulating layer over a metallic substrate. Application for QC in production may be of interest here. In addition, the system will be useful in locating metallic fasteners below the surface including these composed of non-ferrous [[materials]] materials.

Please replace paragraph [088] with the following amended paragraph:

[088] Additionally, multiple IR cameras and induction coils [[and]] can be employed in the current invention, in combination with a single scan or as individual scans of the same unit. For instance, in the present invention multiple users can simultaneously scan a large object, such as an F-16 wing without interfering with other users similarly engaged in the scanning of the object.

Please replace paragraph [089] with the following amended paragraph:

[089] It will be apparent to those skilled in the art that various modifications and variations can be made in the An Inductively Heated Transient Thermography Method And Apparatus For The Detection Of Flaws of the present invention and in construction of this invention without departing from the scope or intent of the [[invention]] invention.